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STUDIES IN INFORMATION SYSTEMS

Effectiveness of Information Systems

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13. ABSTRACT

This working paper is designed to stimulate research into the concept of information system effectiveness. The varied characteristics and purposes ascribed to such systems are identified, including the requirement to support, at least partially, the decision process at one or more levels of activity. Discussion covers the value of information and its impact on organizational objectives. A proposed information-decision model stresses the recurring, dynamic demands for system output. Measures of effectiveness are derived from functional objectives in both qualitative and quantitative terms. Economic and behavioral influences on these performance indicators are considered. Suggested areas for additional research include attributes of information quality, effects on decision making, and relationships of existing models, theories or techniques to information processing.

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I. Introduction

This working paper is intended to establish a framework to encourage research related to the effectiveness of information systems. Management and system users have become increasingly wary of promises about intangible benefits and underestimates of time and resources. Economic conditions have engendered profit or cost centers for service, capital authorization criteria for development, and close scrutiny of operating expenses. Evaluation of performance is thwarted by lack of definition of system objectives, of standardization for development and processing, and of formal assessment methods. Needs exist to integrate various concepts and techniques as well as to intensify study in several of these areas. Our objective is not to present solutions nor to rehash the work of others, rather it is to point the reader and stimulate his interest toward prior and potential future contributions to knowledge about determining information system effectiveness. The ideas presented here are based on a composite of experiences over a number of years and must certainly include assimilation of views and findings from many sources which the author has found to be meaningful and valid. Insofar as practicable references have been made to those sources to give credit and to aid the reader's further study. The more immediate influence on content of the paper has been a discussion group among Lehigh University faculty and graduate students from a variety of disciplines which met regularly during the 1971-2 academic year. If this paper fails to engender further dialogue and/or controversy, it will have failed in its purpose.

Various terms and concepts related to information systems are described in Chapter 2. Discussion covers the major issues which limit understanding of the design, development and operation of computer-based systems. However, the presence of the human component

in such systems and its considerable influence on the realization of success or failure are recognized. We are assuming that an information system may serve widely differing customer, or user, requirements. In every case, however, at least part of its mission is to support decision making at one or more levels of functional activity. The evaluation problems are not severe for systems that stress execution of administrative and clerical activity or control over processes because the objectives and variables are normally defined and constrained in advance. As the decisions become non-programmed and even problem recognition becomes an issue, the possible alternative courses of action explode in quantity and the effect of an information system is concerned with changes in user or decision-maker behavior. Measurement of these effects becomes extremely difficult because objectives are complex, multi-attributed and normally expressed in general terms subject to varied interpretation (Shepard). In such cases, the sources of potentially relevant data are numerous and include both recorded facts and judgments. Obtaining and handling the volume and variegated forms of data become onerous and expensive tasks. Aggregation of the different attributes into an objective function or figure of merit is challenging. Even more important, it is difficult to isolate the quality of information delivered by a system from the results of decisions that are rendered. For an automobile, we can determine the quality of the manufactured product, the skill of the driver, and the existing environmental conditions in order to conjecture about success or failure in meeting customer or public objectives which vary in character and importance. Similar analysis of an information-decision system would indicate:

Information - Quality depends upon accuracy, completeness, and timeliness of input data and the effectiveness of the processing system.

Decision - Quality depends upon availability and content of information and the knowledge, or experience, and logical ability of the decision-maker.

Outcome - Results depend upon the appropriateness and timing of the decision(s) relative to organizational objectives and the validity of assumptions about environmental conditions.

Variables not controlled by the decision-maker and not anticipated by the system designer often have more influence on the outcome than performance during information processing. But the system is frequently the scapegoat for poor forecasts or changed requirements.

Indeed, inadequate knowledge of the decision-making process inhibits meaningful design and evaluation of information systems (Stufflebeam). Variations of the decision process are discernible among individuals and for a single individual in different time frames and circumstances. A composite, prescriptive approach is not practicable in most operational situations. Only the simplest, programmed decision rules avoid heavy emphasis on subjective estimates of: (Savage, Raiffa, Luce and Raiffa, Kriebel)

- States of nature
- Alternative courses of action available
- Payoffs of each alternative
- Value of payoffs in terms of objectives
- Timing appropriate to payoffs

Neither complete ignorance nor perfect information are realistic states, rather a condition of partial ignorance or uncertainty normally exists in which some objective facts are known and judgment must fill voids and aid in interpretation of facts. This uncertainty spawns from the need to make personal estimates based on judgment and subjective impressions or from a lack of confidence in available objective facts (Archer, Schlaifer). When is the objective data a representative sample of actual conditions? How does one combine these objective and subjective inputs? When does accumulated objective information outweigh subjective estimates? When does the cost of acquiring additional information exceed the expected marginal gain in outcome of a decision?

In most cases, these questions are resolved by a feeling of confidence in the system output by its users, being attenuated by time pressures. It has been suggested that only clairvoyance can eliminate uncertainty about these matters (Howard).

Chapter 3 compiles some notions about the decision system which emphasize the dynamic, continuous nature of the decision process (Hodge and Hodgson). Too frequencly, we assume that a decision is made and the problem is solved. Yet information systems are justified and designed to serve recurring needs of users involved in similar classes of problems or in repetitive cycles of:

- Recognizing a need to act
- Identifying feasible alternatives
- Selecting among alternatives in a given time frame.

In general, our model assumes that the system user is confronted with a series of decisions for a problem or related ones rather than an ad hoc state of affairs. The need for information is then spawned in order to reduce uncertainty about the several issues discussed in the previous paragraph (Bedford).

Measures of effectiveness (MOE) are discussed in Chapter 4 in an attempt to link functional objectives more clearly with the parameters that are identifiable in information-decision system output. In so doing, scenarios of functional activity and system utilization may prove invaluable for identifying the key performance factors which influence or signal success in achieving the objectives which an information system is intended to support. Emphasis is placed on tangible measures that can be identified and the aggregation of both qualitative and quantitative factors in a utility based format. Some of the behavioral and economic influences on choice of measures of effectiveness are discussed. Special concern must be given to unintended benefits, which may become the principal justification for an existing system, and either advantageous or deleterious side effects of system use on other functions or systems.

In chapter 5, a number of techniques are called to attention which merit further attention either to aid research or to provide greater insight into the information-decision process. This listing is not

intended to be exhaustive nor are the items to be treated as possible independent solutions. Measurement of the effectiveness of an information system is, in itself, a complex multi-attributed problem. The areas of uncertainty discussed earlier are quite evident and it normally appears easier to avoid evaluation or to make one based on ill-informed judgments rather than to perform a thorough assessment. Further investigation of these techniques and their application to information systems will increase insight into the meaning of effectiveness and feasible ways of measuring it. Perhaps their application will also provide greater understanding of the value of information and the decision process itself.

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II. Nature of Information Systems

Background

Information processing has grown rapidly in importance and financial commitment over the last two decades. Unfortunately, its products are relatively insensitive to the needs of the market place and the customers have shown little discrimination in determining whether or not they received a quality product at a bargain price. The product, called information, is intended to satisfy requirements which the customer, or decision-maker, has articulated. The process which generates information is specified, designed, and developed in the form of a system, that is:

A set of interrelated rules and procedures for processing data into information in order to get or control action.

Note that this considers data to be raw material which constitutes input to the refining and forming process in order to develop a useful product. The purpose of an information system is not to fill archives or to produce yellowing stacks of paper, rather it is to support action on the part of a satisfied consumer. To date, that potential consumer has had to accept what was available too often, having little opportunity to shop or to return unsatisfactory products. Contrary to many beliefs, the product is perishable, often having a well-defined shelf life. Also, the customer needs are seasonal and the market is extremely dynamic in respect to both changes in customers and variants in their needs or uses for information.

The concept of an information system is frequently confused by references to narrow purpose computer applications, but the essential attributes include:

- Single organization orientation. The information system is tailored to serve the objectives of an organization and to meet the requirements of persons within the organization.

- Integral to the organization. The information system is functionally and technically integrated with the organizational structure and flow of communications implied therein.

- One of a kind. An information system should be designed and developed as a major construction project rather than assume it is a prototype for a number of similar systems.

- Evolutionary change. The design should accommodate flexibility in use and modular replacement so that the system can be modified to meet dynamic requirements while remaining operational. Obsolescence must be low because a complete replacement model will rarely be feasible.

- Software is critical. The heart of the information system is composed of procedures and programs. Hardware supports these, but related more to efficiency rather than effectiveness of the system.

- Humans are major components. Information processing requires a man-machine system in which the performance of humans is a major influence on cost and effectiveness. Consideration must be given to human roles during processing as well as interfaces at data gathering and information utilization.

Table II-1 describes several tentative classifications of processing characteristics which are intended to aid in conceptualizing information system purposes. Normally, several of these characteristics will be required or specified in a system which meets organizational purposes.

Failure to serve the demands of the consumer market for information usually results in systems which are unused or which consume great effort for little success (Hodge and Hodgson). Technical successes often fail to achieve economic benefits or operational acceptance (McKinsey) and projected growth of scope and importance of information systems (Diebold) is inhibited. False assumptions are frequently made about the nature and volume of data needed by decision-makers and about the ability of information to actually improve performance of an

Table II-1

Processing Characteristics

Planning	Models to project and forecast based on historical trends and estimates of the future. Normally requires a representative sample data base rather than live operational data. Interactive mode of operation is highly desirable.
Management	Analysis of the utilization of resources by functional managers. Requires complete actual data. Mode of operation is usually batch-oriented unless decisions are related to short cycle period.
Communication	Transmission of messages among remote sites. Requires proper distribution of input without interpretation or alteration of content. Normally requires on-line processing with store and forward capability.
Data Base	Collection of data and storage in computer-based files for future access to content or facts. Requires frequent, if not continuous, input of data from a variety of sources. Normally requires on-line inquiry mode for effective delivery of output.
Monitoring	Gathering and analysis of data from a specific process or operation on a continual basis. Normally involves on-line capturing of digital and/or analog data and immediate feedback to control the operation.
Reference	Retrieval of documents or references thereto, often based on material stored in microform, technical papers, and other media not computer-compatible. Initial reference is often accomplished by on-line computer operation. Delivery of the desired input is normally an off-line, batch oriented library process.
Scientific	Algorithm oriented processing related to calculation for analysis or estimation of operational data. Includes statistical and engineering calculation. Processing is normally done in batch mode but input may be collected on-line or aggregated for subsequent processing.

organization (Achoff). Evaluation is correctly identified as the weakest milestone (Kriebel) in developing management information systems today. There is little wonder that this is true when the customer has so little understanding of and selection in the product he receives. Better evaluation is additionally important because system output is normally consumed internally by the organization and its low quality or lack of use compounds the burdens of expense and dysfunctional actions.

Value of Information

Probably more than enough has already been said here and by many others about the distinction between data and information. Unfortunately, it is often treated as a matter of definition rather than a design philosophy or an evaluation criterion. Effectiveness of an information system must be related to the quality of its output. Value of information is then determined by analysis of both the effectiveness of the system in delivering a quality product and the cost of delivering that output to the customer.

Quality of information is described in terms of benefits in a given situation, that is impact on the behavior of users or on the resultant action in a decision and/or control process. The benefits are expressed in terms of ability to reduce uncertainty about:

- Need for action
- Existent or anticipated states of nature
- Recognition or selection of alternative courses of action
- Expected pay offs for each alternative
- Timing of decision and action.

Assessment of these benefits is normally based on personal judgment, often without understanding the full scope and capability of the information system. The effects of actions can be more objectively determined, but they are frequently observed and influenced by other activities beyond the control of the decision maker. Often, more than one information source is used by a decision-maker and it is difficult to determine the relative contribution of each.

Costs are rarely as obvious as charges for computer services might indicate. The user of the system may consider only his personal time and effort to access and utilize information. A given decision situation may imply employment of more than one information system or only a part of a more comprehensive one. Correct allocation of the data gathering, processing and information dissemination costs must be combined with those of personal commitment by the user to be consistent with derived benefits. Over-sophistication of the system or unnecessary emphasis on one attribute of information can also produce excessive cost relative to the resultant change in benefits or effects of decisions.

The attributes which are most commonly ascribed to information are difficult to assess and almost impossible to measure separately (Langefors). Rather than being inherent properties in system output, they are important only in the context of operational functions served. Perhaps we should reflect on the characteristics of these attributes:

Relevance - Judgment on the appropriateness of the message content received.

Accuracy - limits of correctness of content based on standards which are often vague and subjective. Sometimes confused with level of detail.

Timeliness - Can be measured in terms of time units or relative to operational cycle. Adverse situation is clear when message is late or causes delay.

Sufficiency - Judgment about the scope of message content and its ability to satisfy all requirements based on the user-estimate of need.

Conciseness - Judgment about the proportion of message content which is utilized in a given situation. Depends upon the mode of presentation. May be represented by a signal/noise ratio.

Reliability - Judgment about the consistency of the data source and personal confidence of the user.

Discovery - Judgment about the news value of message content subject to variation in personal experience and recall.

It is not difficult to agree that an adequate message has news value, bears upon the problem at hand, was received in time, and satisfied the user. Determination of the perspective of each attribute and the value of information is, however, tenuous at best. For example, does timeliness refer to preparation of a report, its receipt at some destination, ascertainment that it is correct, or its use by a decision-maker? How does decay and shelf-life relate to this attribute?

Let us assume that we do have a response to user demand that is timed and structured to be useful in a decision making or control task. The message can be responsive to a periodic need, to a predetermined exception status, or to an ad hoc inquiry. Perfect information would indicate uncertainty had been removed from the situation, that is the message(s) received met all attribute criteria in relation to user background and experience. It is more likely, however, that an imperfect information situation will exist. This can occur in one or more of several ways, given messages which are:

Incomplete - insufficient content.

Uncertain - accuracy, reliability, or sufficiency are in doubt.

Incongruous - lack of relevance, accuracy, timeliness or sufficiency indicates incompatibility of content; discovery promotes contradiction with experience in some cases.

Superfluous - excessive content which does not discriminate relevant or discovery items.

Presence of these faults promotes subjective estimates by a decision-maker and a circumstance in which he is satisficing rather than optimizing on the basis of some true value of information.

Organizational Impact

We have stressed the interdependence of an information system and the functional objectives of the organization that it serves. Figure II-2 outlines the major levels of activity encountered in an

Table II-2

Activity Levels

Title	Description	Information System Implication
Strategic	Planning and policy considerations related to future time periods or resources. Goal-oriented and horizon extends beyond normal information system support coverage. Decisions are non-programmed and require extensive deliberation.	The information system must provide a meaningful data base for forecasting. Little objective data bearing directly on area of study is available.
Tactical	Planning and selection of alternative courses of action for several existing operating units and/or proximate time periods. Supports scheduling and utilization of resources in current accounting period. Decisions are non-programmed unless constrained by policy or short term plans.	Summary and analysis of performance data which must support functional management needs.
Operational	Immediate supervision, monitoring or control of resources applied to ongoing activity. Concerns current cycle of operations (not arbitrary time periods) and programmed decisions.	Requires feedback and continual processing to provide support within the operation time cycle.
Clerical	Performance of assigned functional tasks by applying available resources. Concerns established procedures necessary to accomplish an assignment or process.	Reports of completed tasks become basic input to the information system. Includes record-keeping and conditioned reactions to transactions.

organization and the implied nature of support which an information system is expected to provide. Both the organizational managers and the systems designers must face these basic concepts in order to establish objectives for the system. Several cardinal points are usually ignored or forgotten in the tempest of development effort, namely:

- Input data should be generated as a byproduct of the operational tasks performed.
- Amount of output and flow of data should be minimal for purposes served.
- Health of the organization depends on appropriate actions, not extensive records.
- Planning and non-programmed decisions depend upon representative samples of activity, not live reports of current conditions.

Failure to establish these concepts has resulted in systems that are over-designed, excessively expensive to operate, and not used to potential by their intended customers. The levels of activity should be served by a cascade of information processing approaches which are highly dependent upon processing at lower levels and integral with functional activities. New information services are then justified on an incremental basis of effort, cost and benefits from likely use.

At the least, the design of an information system is a master plan which is developed by a top down view of organizational objectives. Implementation may start at the lower activity levels, but only for those tasks which relate directly to priority objectives of the organization. Too often, the information system is conceived and built as an end in its own right -- a sterile, redundant effort. Elegance of design or ease in operation become the system objectives rather than acceptance and utilization by the prospective customer. In that regard, a successful information system must be a compromise between designer and manager purposes. Dialogue to arrive at a compromise promotes understanding of functional goals, assessment of

organization and communication, and definition of needed information. As in a computer application, perhaps this introspection provides a greater contribution to success than implementation of a perfunctorily correct system.

Although earlier attempts to develop information systems have not been eminently successful, this does not infer that their impact on organizations has been minimal. Issues of centralization or decentralization both of the organization and of information processing responsibility have been given substantial attention (Whisler, Emery, Delehanty, Brink). Changes in organization and group dynamics have generally occurred, but they are only infrequently attributed directly to the advent of a system (Vergin, Blose and Goetze, House). These have included staff relocation, realignment of communication flow, redistribution of missions and reallocation of resources (Davis). Patterns of control over activity have shifted because of the availability of new information sources and by abdication of management responsibility to system designers. Routine or clerical tasks have been assumed by systems, middle manager responsibilities have been squeezed, time for action has been compressed, and more complex tasks have been undertaken (Whisler, Emery). Methods of gathering information and making decisions have changed for individuals (Schroder, Carroll). The impact has also been evidenced in resistance to new concepts encompassed by information systems and in reaction of management, worker and system personnel to implementation (Dickson and Simmons; Dickson, Simmons and Anderson; Brady). Perhaps the most significant evidence of the interplay between information systems and organization lies, however, in the existence of informal organization and flows of communication. Failure of the formal organization to provide action and information as needed has forced individuals to seek their own sources. To be successful, a well-designed and effectively operating information system must meet this challenge and minimize the informal flow of information, particularly in areas which are not related to organizational politics.

Hierarchical Views

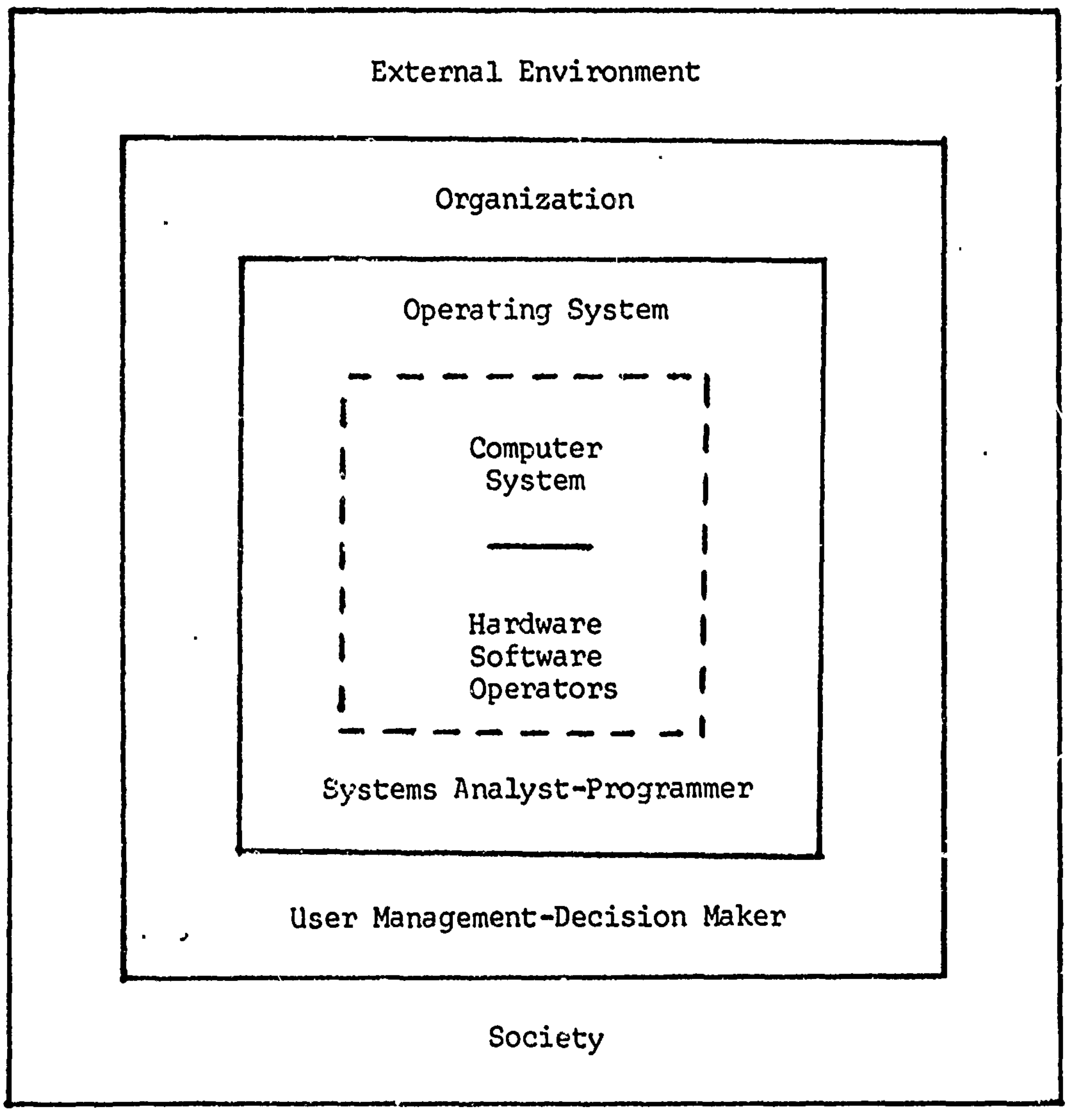
One important aspect of an information system which confounds evaluation of its effectiveness is that it is perceived differently by various persons. This is summarized in Figure II-1 which shows the hierarchical relationships. At the core is the computer system which focusses on hardware and software performance. At the outer layer is a society which imposes constraints on the organization and is the recipient of its products or services. Success at one level is normally determined in the next outer layer which is partially outside of the sphere of control of the level being assessed. Effectiveness and efficiency are dependent upon performance in the layer under view and in all of those within its boundaries. The ubiquitous systems analyst can appear at any level but, all too often, he is oriented to the hardware-software issues.

Performance Measurement. The inner view of the hierarchy relates to speed of computer operations, throughput of the computer system, capacity utilization of hardware, and response time to the user of the system. The scope of the entire system and its timeliness are completely dependent upon performance at this level. However, these do not guarantee user satisfaction or organizational success. Given several methods of achieving desired benefits or effectiveness, however, performance measurement can compare these alternatives and select the most efficient or economic one. The basic measurement tools are:

- Operation time
    - Figures of merit based on memory capacity, word size, data transfer rate, main memory cycle, instruction execution time
    - Mix of instructions, modules or subroutines
- Program execution
    - Actual applications for new configuration
    - Benchmark problems

Figure II-1

Hierarchical Relationships



- Mathematical models
  - Weighted performance factors
  - Simulation
- Monitors of activity and status
  - Hardware
  - Software

This subject area has received substantial attention and recent literature contains many good references on operating measures and techniques to evaluate systems from this viewpoint. Simulation has particular merit in measuring and predicting performance for dynamic systems which interact with the user interface.

User Interface. Much has been written about the importance of this view of the system and most of this text refers directly to it. The information system is a special case of man-machine systems and must consider the many human factors issues (Meister and Rabideau). Emphasis is placed on articulating and serving user requirements which are responsive to decision-making in order to meet organizational objectives (Smith and Wolf, Heany). As an extension of organizational impact, it is redundant but important to stress the active participation of the potential user in conceptualizing and proving information systems. Both the effectiveness of a system and its utilization depend upon the understanding and confidence generated at this level.

Environment. Revision of organizational objectives and evolution of information systems depend upon intelligence from the external environment. The major environmental influences on the effectiveness of information systems are:

- External factors
  - Technology
  - Market and competition
  - Political and governmental
  - Economic (GNP, employment, productivity, prices, wages)
  - Demographic and social
  - Public interest and acceptance

- Corporate factors
    - Resources available
    - Personnel capability
    - Management policy and perceptions of external factors

Ultimately, the success of the information system must be gauged against the ability of the organization to adapt to and find acceptance in the external environment. This places heavy emphasis on the role of information to support organizational planning.

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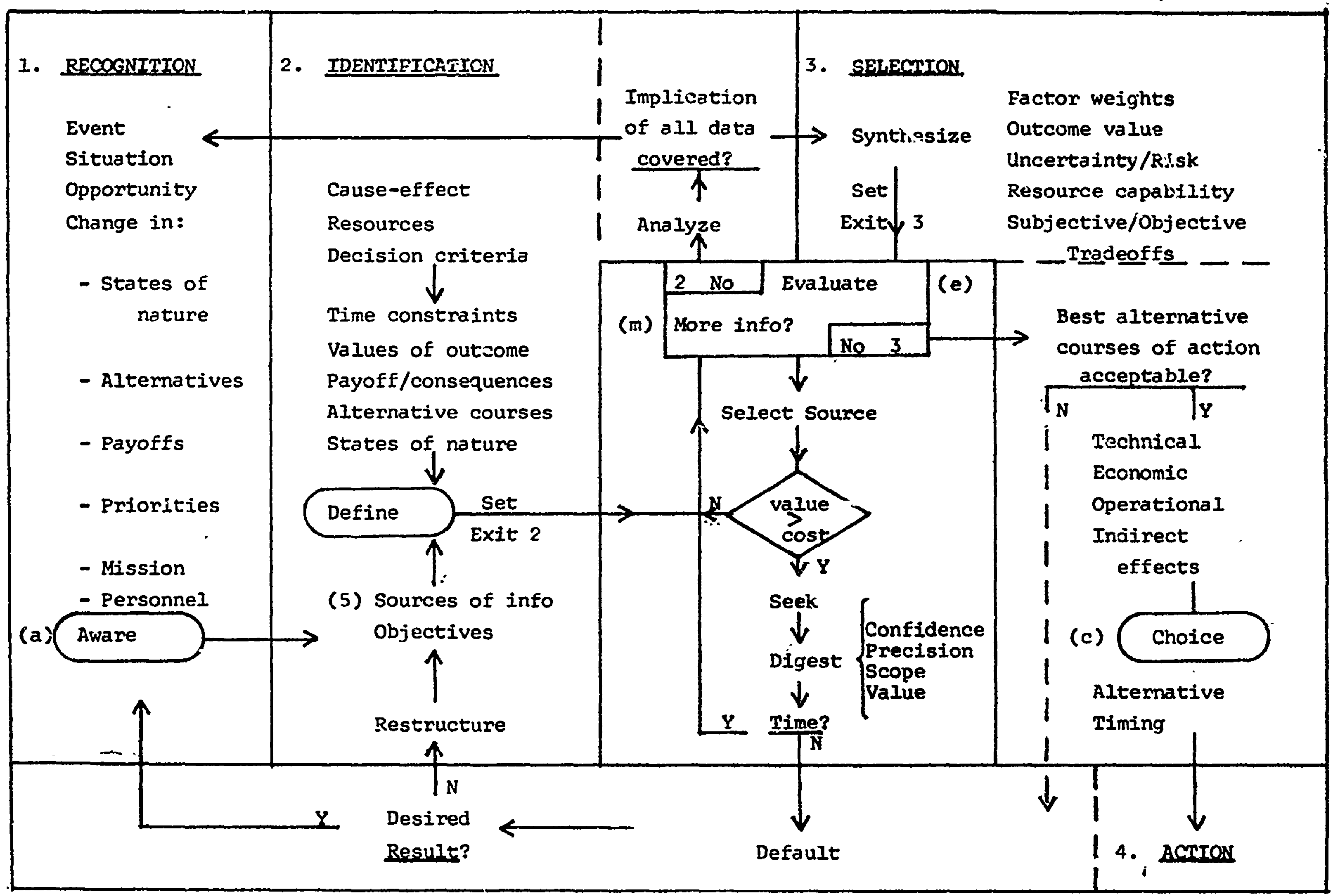
III. Decision System Model

We have discussed that information systems must, at least in part, support the decision-making process. At the clerical level of activity, they tend to displace manual effort on repetitive manipulations which change slowly. At the operational and tactical levels, iterative decisions are rendered on similar classes of problems with intermittently changing parameters and condition variables. Operational control cycles tend to be short and regular with well-defined independent and dependent variables. Often the states or values of independent variables are continually updated by transactions generated directly from the functional task to be controlled. As the level of activity becomes more planning oriented, the nature of the task to be accomplished becomes less structured and it may be difficult even to perceive the problem.

Thus, routine activities may involve only reaction to transactions which are introduced to the system from external sources. However, at the tactical level a system may make information available to aid awareness and definition of problems and to choose among alternative courses of action. Figure III-1 indicates the major tasks of this decision process and the manner of using information to support them. Recognition of the need for a decision to control or initiate action may come from a number of sources, including analysis of available information related to ongoing activity. Both identification of the decision problem and selection of a course of action depend upon repetitive interaction with sources of information. Each decision-maker must evaluate the status of objective facts and personal knowledge in order to determine his need for additional information. Having identified the appropriate source, he judges the expected additional value in contrast to the cost and effort of acquiring more information. Unless time constraints or changed circumstances terminate the process, a course of action is normally chosen and implemented. Because of the uncertainties about the true state of the several variables, results rarely involve complete and lasting satisfaction. This often suggests a heuristic approach to identify and

Figure III-1

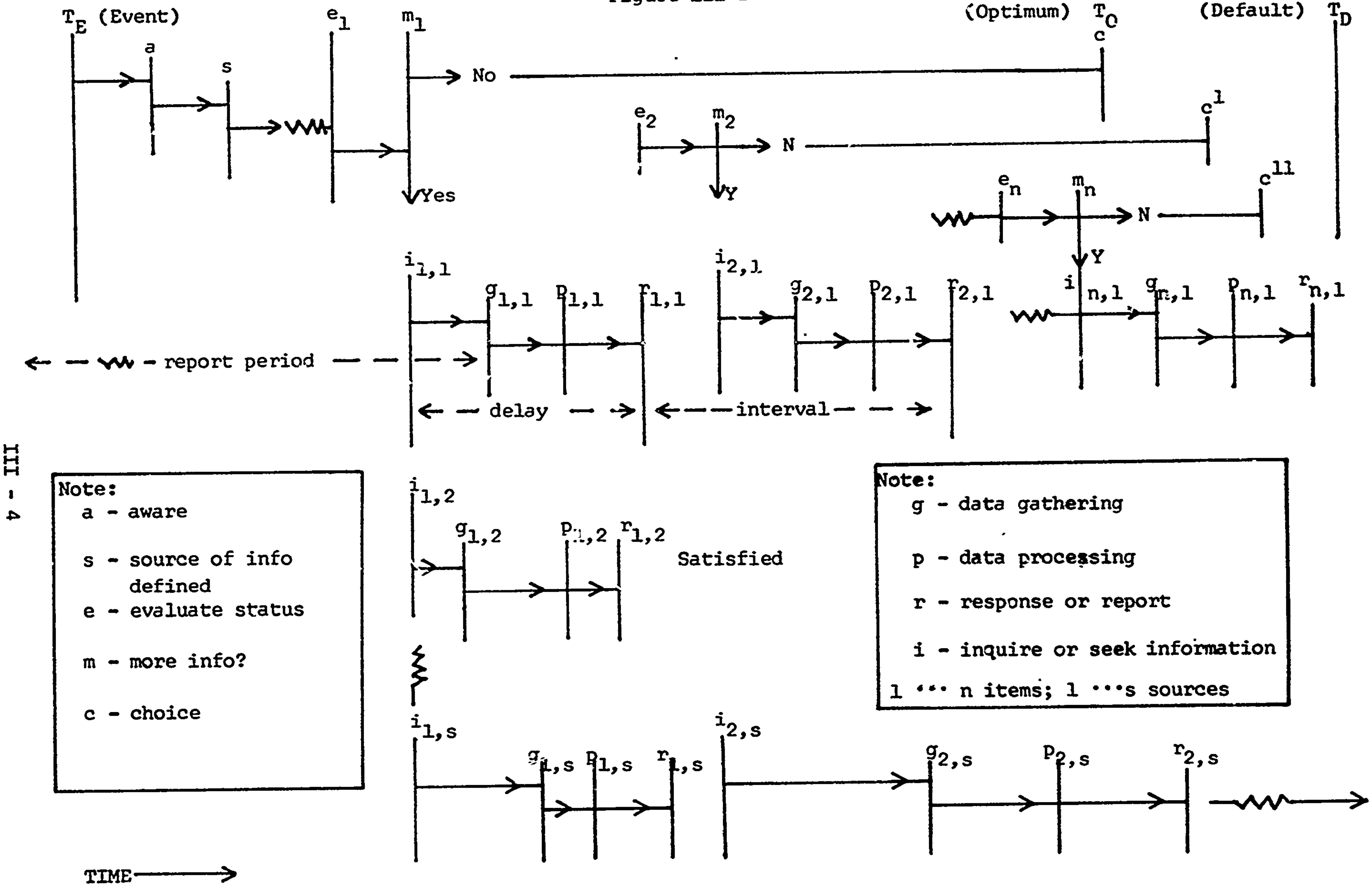


DECISION PROCESS MODEL

select courses of action which are compatible with the set of organizational objectives. Failures in execution or proper timing of the action also require a series of related decisions to produce desired results. Many systems at the lower levels of activity are intended to monitor changes in events outside the system and to react at recurring intervals to the aggregate implications of these events. Additionally, an iterative decision process may be suggested by appearance of undesirable side effects which were not anticipated by a proposed solution. To support these series of related decisions, it is presumed that there is a need for continual synergism with various sources of information. An information system is justified by stable requirements for information or by high potential benefits from this dynamic process.

The recycling aspects of the demand for information and interactions with the decision system are amplified in Figure III-2. Significant times are indicated by the emergence of an event, situation or opportunity which will require action (T_E); the optimum point to implement an action (T_O); and the limit beyond which any action is ineffective (T_D). This latter default limit results from a failure to make a choice among possible courses of action (one of which may be "no action") rather than to consciously allow conditions to ride as a best alternative. The figure then shows the information processing involvement that emanates from a decision to seek information about one or more variables from several sources. An inquiry may define retrieval from a data base, initiate data gathering, or request a report at its usual time. The delay of the response will depend upon its nature and the relative effort to meet outstanding inquiries. The figure indicates that repetitive requests are normal and that choices are often made before all desired information is received and digested. Report periods may include time before the event occurred and commonly overlap on successive requests, having greater time span than the interval of inquiries. This dynamic process can become an entrapment in which the decision-maker focusses on information processing, or its failures, and defaults on the needed decision.

Figure III-2



DECISION-INFORMATION INTERACTIONS

In short, the effectiveness of an information system is highly dependent upon a decision process which is not always well understood nor amply accommodated by a system design which fails to recognize the dynamic, open system characteristics. The model we propose for consideration here is neither formal nor comprehensive. We do suggest that it embodies several concepts that directly influence the consumer demand for information. The recycling characteristic seems to apply whether the decision relates to determining objectives, structuring procedures, modifying control by use of procedures, or reacting to events. It is apparent that the need for a decision does not depend nor wait on the convenience of the decision-maker to construct a list of alternatives and their possible consequences (Thompson). Thus, inappropriate decisions and failure to take action in necessary time are tangible considerations. In such cases, what is the culpability of an information system which responded to inquiries without undue delay and provided output well worth the cost of producing it?

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IV. Measures of Effectiveness

We have discussed earlier the difficulty in directly assessing the value of information from intrinsic attributes of system output. It is necessary, therefore, to identify parameters or dependent variables which indicate the level of performance in some essential aspect of a system. Commonly, such a measure of effectiveness (MOE) is an operational factor which is expected to vary in relation to the impact of an information system. One or more MOE is usually derived from each benefit which the information system is expected to deliver. For tangible benefits, an MOE should be quantitative in nature and based upon objective data. Substantial reliance on intangible benefits to justify information systems suggests that some qualitative factors based upon subjective opinions are normally appropriate. The MOEs for a proposed system should be developed during the system definition stages following the general procedure:

1. Define functional tasks to be served by the information system(s). This specifies the planning, control, supervisory, and clerical involvement of activities and decisions.

2. Define the goals of each information system. This includes the functions it serves, and its principal processing characteristics.

3. Develop scenarios of the operational situation. These describe the interactions of the system(s) and their users as tasks are performed and various problems encountered.

4. Determine performance parameters based upon operational considerations.

5. Measure the current level of performance for each parameter. Standards and criteria of satisfactory performance may be available.

6. Estimate improvement of the level of performance for each parameter after implementation of the system. This would normally involve a range of estimates based on optimistic, likely, and pessimistic premises.

7. Relate each parameter to the expected benefits(s). This involves estimating the relative contribution of each parameter to effectiveness in performance of tasks. On this basis, credit for achieving benefits is allocated among efforts which influence results.

The principal difficulties related to use of resulting MOEs are handling qualitative or subjective parameters, weighting and aggregating related factors, and trade offs among MOEs measured in different units (Hormann, Stufflebeam). Most of the decision problems encountered deal with multi-attributes, some of which are based on hard facts and others on judgment. It is rare that the most significant attributes are measured in the same units, such as the convenience of comparing all benefits and costs in terms of dollars. As we have discussed earlier, users of the system are continually judging its worth. An evaluation study nearly always solicits opinions about the effectiveness of the system, satisfaction in its use, and recommendation for revision. The opinions must be compared among groups of individuals for each parameter and the composite view scaled in relation to some arbitrary criteria of desired performance. Well defined situations promote standards, or points of reference against which values can be compared. (For instance, a MOE of "indirect/direct employees" might have the standard value of .35.) They are rarely adequate, however, for the complex aspects of an information-decision system. Limits of desired performance in such ill-defined circumstances require consensus in operational terms for each MOE, whether qualitative or quantitative in nature. Additionally, various measures must be weighted to show relative contribution to achievement of a benefit. This involves judgment about and scaling of the relationships between MOEs and benefits. Ordinal scales, usually the best one can do in such open systems, are insensitive to trends in the level of an MOE

and in relative impact among several MOEs (Coombs). Both the presence of subjective factors and the lack of common units of measure suggest utility as the common denominator in any logical combination of MOEs into an objective function (Miller and Starr; Spetzler; Srinivasan; Stevens; Swalm).

It is important to realize that the levels of activity served by an information system strongly influence the nature of MOEs established. Table IV-1 shows the dominant pattern in very general terms. The functions served by the system and the form(s) of processing utilized suggest benefit-oriented MOEs. Suggested MOEs for various organizational functions apply primarily to the tactical and operational levels (Stokes). Expected system performance can also be described in a profile of issues related to user requirements or expectations. This is useful for planning and evaluation purposes at all levels (Hare; Smith and Wolf). It must be remembered that most systems involve a variety of activity levels, forms of processing, and areas of operational support which confound and expand MOE definition. All too frequently, however, the differing character of performance parameters at various levels is not considered and evaluation is focussed from a microscopic view.

A scenario is particularly useful in developing MOEs and in assessing their relative contributions before systems implementation. It consists of a description of the environment, tasks and roles associated with an operational situation. The sequence of events and interactions among users and systems are described for several typical tasks or problems. The script can center on a function with its support system(s) or on an information system with the populations and functions it interfaces. Given initial conditions and logical sequences of events for its several components, the scenario can be used for gaming or observation of man-machine interactions. In particular, the following can be assessed and extrapolated to actual conditions:

- Perception of sources of information

Table IV-1

Characteristic Performance Indicators

Activity		Dominant Issues	Example MOEs
Clerical	Function:	cost displacement; task execution	Units per labor hour, backlog
	System:	efficiency; speed of operation, economy	Throughput, capacity utilization, data preparation cost per unit
	Information:	accuracy	% error transactions
Operational	Function:	monitoring and control over activity and resources	Inventory level, yield rate, messages delivered/received, missed shipping dates
	System:	maintainability; sustainability, availability, sensitivity	% down time, time between failures, frequency of service, % requests with special handling
	Information:	timeliness, reliability	Response time
Tactical	Function:	Decision quality; functional objectives	Return on investment, volume orders per district, unit cost, overtime/regular hours, % returned product, delivery time
	System:	auditability, compatability, flexibility, security, scope	Actual users vs. intended users, % service of total cost, reports returned vs. delivered
	Information:	sufficiency; conciseness, discovery	% file used when appropriate, volume of inquiries
Strategic	Function:	organizational mission, planning, outcome of decisions	Share of market, new products, earnings/share, change in risk, % R&D of total expense
	System:	user satisfaction*	Number of accesses per inquiry, time to formulate inquiry, % compliments vs. complaints
	Information:	relevance	% responses appropriate

*Access ease, available period, dependable source, suitability to purpose, personal convenience

- Effort and assistance required to form an inquiry and/or interpret a report.
- Number of accesses or reports necessary to satisfy an inquiry.
- Use of information by participants
- Interdependence or redundancy among systems or functions.
- Options and possible alternatives at various times.
- Transient aspects and fluctuations in conditions or information.
- Likely consequences of courses of action.
- Relationships of performance indicators and goals.
- Sensitivity of results to assumptions and independent variables.
- Realism of MOEs and standards.

The scenario of an existing situation may give insight to possible unintended benefits or changes in requirements which are frequently encountered in established systems accessible by a variety of users. Often these benefits will outweigh the initially stated ones and cause shifts in expected user populations and purposes. For a meaningful scenario, particular attention should be given to the circumstances under which people interact and seek information support. This can assist in judging the value of system output and in validating measures of effectiveness.

The procedure for identifying MOEs usually generates a host of candidates. Only those which correlate highly with benefits and also prove to be uniformly understood and applied should be retained. Hopefully, a weeding and pruning process will yield a handful of significant MOEs meeting the following criteria:

1. As few as possible selected.
2. Apply both to present and future projections.
3. Lead to worthwhile ends.
4. Lead to progress and innovation.

5. Permit ready comparisons (Stokes).

6. Ordered and compacted so as to be mutually exclusive.

Also, an overriding factor relates to determination of the value or level of performance of an MOE at any given time. The most successful ones will be included in system specifications and will produce values as a by-product of normal functional operations. This affords frequent measurement and minimizes both the cost and opportunity for bias associated with separate data collection solely for evaluation purposes.

Economic Aspects

Some measures of effectiveness incorporate cost or financial benefit premises. Often these figures are determined directly from accounting records. To the extent possible, this provides convenience in collecting data and in accumulating the various MOE contributions during review of performance. In most cases, however, the economic effects will not be so readily available. Then the estimation of performance level is difficult because cost and benefit factors cannot be compared on a single scale of measurement units. Cost effectiveness assumes that a single attribute (or a couple of compatible ones) will be utilized as the base unit for an objective function. Further, correlation of input and effects should be known and high. This approach can be meaningful to compare alternatives which are competing for funds at relatively fixed costs, or which provide relatively the same performance at varied costs. However, this is generally an oversimplification for the complex, multi-variable situations served by information systems. Benefits for operational activities can often be expressed in money terms, but expected utility of this return may vary substantially. Deleterious side effects which were not anticipated are rarely reflected in MOEs as a cost or a limitation on effectiveness. The cost factors for an information system should cover user involvement and results from late or misleading output. Such effects are difficult to express in tangible terms. These and related issues complicate the identification and formulation of sound measures of effectiveness.

Behavioral Aspects

Although measures of effectiveness and their relationships with controllable variables may be known, individual reactions to a situation usually vary. Different risk and utility attitudes cause diversity in choices among alternatives based on the same information. Fluctuations in confidence or satisfaction of the decision-maker in the system may alter informally the weights given to various factors. These may also cause differences in tradeoff between subjective judgment and objective reports supplied by an information system. The nature of reward or reinforcement provided after decisions have been made alters the preferences, priorities and risk philosophy applied to future decisions. These various influences and individual or group differences cause bias and deviation from norms expected to result from uniform perception and use of performance parameters.

The process of aggregating a number of factors to an objective function is another source of behavioral influence on significance of an MOE. Normally, one assumes a compensatory tradeoff and combination among the weighted performance factors. However, in a given circumstance, a disjunctive strategy may be adopted in which one MOE dominates all others and compels a choice. Similarly, a satisficing approach to alternative selection may be adopted. That is, one seeks the decision which meets the minimum threshold on all factors and has support from affected parties. The latter, in particular, tends to truncate the information seeking process and to limit the achievement in terms of the chosen MOEs in favor of a more expedient disposition of the situation.

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V. Areas of Research

This paper has stressed both the difficulties in measuring information system effectiveness and the fact that it is not an isolated problem. A range of characteristics and purposes can be attributed to an "information system." A proposed decision model sketches the dynamic, intermittent interactions between the system and the decision process which it serves. Dependence upon organization structure and style is indicated. Man-machine system concepts apply in a synergism of computer programs and manual procedures. Individual differences among users and shifts in operational priorities create a fluctuating demand for content, form and amount of information. In all, the concept of information quality requires further exploration and definition in terms of the operational environment.

Progress toward a more comprehensive system theory would provide greater insight about the role of information in purposive systems. Proven methods for analysis and design of systems and programs are far from uniformly accepted and applied. The major phases of information processing themselves suggest many practical topics which will benefit from continuing applied research:

Phase	Example topics
Data gathering	Errors, instrumentation
Data recording	Conversion process, media
Processing	Hardware/software selection, operating system, program structure, data flow, performance criteria, cost allocation, logic development
Storage	File structure, data management
Dissemination	Media, method, format

The principal concern addressed in this manual, however, has been the use and impact of information system output. The areas outlined in the following sections are suggested for separate study, for collating into a procedure, or for transfer of application from other problems to those related to information systems.

Study Approaches

Methods of measuring effectiveness are included for investigation because of their important use in the conduct of research, but also because they should be the object of further development. More should be known about the most appropriate method for a given set of circumstances. Analytical models may prove adequate and appropriate for some aspects of systems. It is more likely that simulation models will be more successful because of the dynamic, complex nature of the performance encountered. Field study is quite common and takes several forms:

- Evaluation studies (Arinc; SDC; Smith and Wolf; Westat)
- Performance measurement (Karsen, Karush, Knight, Chapter II)
- Observation and analysis of activity (Heiland and Richardson, Reuter, Richardson)
- Judgment surveys. Adaptations of the Delphi technique will prove useful to gain consensus about ill defined objectives and about opinions concerning effectiveness from differently biased observers. (Smith and Wolf)

Experimental laboratory approaches are possible but, because of the behavioral involvements, they are usually linked with gaming approaches (Barkin; Cohen and Van Horn; Davis and Behan; Lopez; Robinson and Stidsen). Particular attention should be given to developing in-basket techniques both as a tool for analysis of operational situations and for experimentation with and observation of performance under controlled conditions. Despite the easy reference to scenarios for such studies, there is little evidence about success in their use. Guidelines for writing and validating them would be valuable contributions.

Human Behavior

The human is critical to information system effectiveness in his several roles as designer, implementer, component, and user. How does one classify the nature and extent of a change in behavior which

results from receiving information? Should output be factual as in an administrative traffic system or should it be influential as in a political message? The intermittent receipt of information suggests issues related to learning, heuristics and group dynamics. Engineering psychology and the ability of the human as an information processor relate to the output a system should or can deliver.

The area of decision making deserves particular research attention, primarily in such areas as criterion formulation, utility and risk attitudes, reinforcement, preference ordering, and choice selection. Of growing importance will be the mutual considerations of organization and information system design (Carzo and Yanouzas).

Cost/Benefits

The central issue of the effectiveness problem is the comparison of costs and benefits. As we have indicated throughout the paper, the benefits are commonly intangible and difficult to agree upon or measure. Although costs have been given attention from the accounting viewpoint for many years, allocation procedures are not well-defined in complex situations. Broader use of systems engineering approaches, stressing dominance of overall organization goals, should clarify many points in this area. Both education of managers and more flexible tools to assist application are necessary. Cost effectiveness and PPBS must become managerial attitudes rather than narrowly applied procedures. Positive and negative effects of information systems must be translated into a net or aggregate of benefits. Costs, including sociological scars and political failures, must be drawn into comparable terms for analysis. The size and nature of systems discussed will mean long periods of development and maintenance. Greater consideration needs to be given to the worth of intermediate goals, amortized values, and extent of commitment, both management and resources, implied by embarking on the extended euphoric trip to better information.

Models

Stochastic models may, in some cases, unlock part of the artistic areas of information system design and allow progress toward more

scientific approaches. Bayesian models and subjective aspects of probability are of particular concern to the decision process being served.

The problems of describing and analyzing flows of data in an organization remain despite several furtive contributions. Matrix approaches have proved to be computationally feasible for a relatively small number of data elements and functional activities. (Homer; Taylor, Schmidt and Ghare; Stults; Wilson and Smith). The effects of data omissions and errors on time and quality need greater understanding. Network approaches have the potential to deal with feedback, time relationships, and reliability of events. Both GERT and Industrial Dynamics should be explored to assess their full capability in measuring effectiveness (Roberts, Forrester, Pritsker and Whitehouse).

Optimization and mathematical programming approaches are applied to many systems with more tangible and finite output. Both limitations and possible application of the various techniques should be explored. Also, algebraic approaches to solution of information system design problems should be considered further (Li). One particular concept, fuzzy sets, has some appeal when dealing with partial or aggregate specifications, changing criteria and grouping of attributes, and ranges of values measured (Zadeh, Hormann).

Theory

Uncertainty and risk are areas which need to be understood thoroughly by an information system designer. Decision theory establishes some norms that are useful in concept. But it appears to have limited practical value in relation to the many uncontrolled variables encountered in most operational situations. Decision analysis bridges the gap and deals more directly with the subjective probabilities related to uncertain situations. Utility and value theories, on the other hand, are more descriptive of the acquisition and utilization of information of various kinds by a decision-maker. These theories suggest a static individual characteristic which is not consistent with observed performance. The need to recognize and accommodate different preference sets, based on variations in

experience and environmental influence is apparent. Relationships between individual and group utility also need exploration.

Particular attention needs to be given to communication theory (a label I prefer to information theory for Shannon's work). Despite its limitation relative to influencing action, the entropy and amount of information concepts have not been exploited to the advantage of better system design or performance (Marschak). The multistage aspects of data processing, information flow and decision making require much greater attention to control theory and Markhov processes (Hodge and Hodgson). The latter are important, not just because information should aid control over activity, but primarily because the system is a process which itself must be subject to sophisticated control.

Although game theory has had little practical application, it or an adaptation may become an aid to the operators of a system for describing or limiting its capabilities. Efficiency of performance and balance of system configuration depend upon understanding and applying queueing theory. Users, transactions and problems all develop their waiting line and service profiles which vary widely. Pattern recognition and related cognitive and perception theories have potential for contribution in relation to media or format selection and to development of order and simplicity in human-system interactions.

A final area for additional research is related to sensitivity analysis. This is crucial if cause-effect relationships are to be identified. Reactions to faulty input, to normal fluctuations in input or processing, and to environmental influences must be more easily gauged. This requires investigation and improvement of measuring and scaling techniques for both quantitative and qualitative variables. It is imperative to have better ways to define the independent and dependent variables, to test the relationships, and to provide representative data for study purposes. Knowing the causal and magnitude relationships of effects will allow tuning of system performance by controlling variables selected during design.

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